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Sustaining the economic growth for agriculture sector in Benin[#]: How do agricultural technologies influence the growth rate?

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This paper examined the influence of agricultural technologies on the growth of agricultural value-added based on time series data (1990-2016) and Cobb-Douglas production function. The results indicated that there are significant and certain benefits to draw economically from the utilization of a system of technological innovations including mechanization, renewed capital stocks, as well as temporary annual cropping and permanent cropping practices. Farming practices involving crop rotation, multi-cropping, and agroforestry are recommended for sustaining agricultural sustainability since they seem to be economically viable and environmentally friendly. It is found that technological innovations pertaining to both soil irrigation system and chemical fertilizers might be beneficial to agricultural production growth when they are managed in accordance with soil characteristics and in a balanced way, respectively. The results also showed that the labor force, the forest area, the amount of credits to agriculture, and the amount of energy consumed to power irrigation are likely to be insignificant to boost directly the growth of agricultural value-added. Thus, the various issues raised in the process of using all agricultural technologies must be addressed either by policy or by appropriating the knowledge relating to their good management so as to make them more profitable to agricultural economic growth.

Key words: Sustainable economic growth, agricultural technology, Cobb-Douglas production function.

INTRODUCTION

A key challenge the world is facing today is how to grow food sustainably, meeting the demands of a growing population without degrading our natural resources base, so as to secure our common future. Responding to this interrogation, the United Nations advocate the adoption of resource-conserving technologies and sustainable

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production practices in agricultural field[1].

In recent years, agricultural production increasingly depends on science and technology advances, farm infrastructures, fertilizers use, pesticides use, planting structures for crops, water management and policy for agriculture development. Different input factors have different influences on agricultural production. For instance, while the Integrated Pest Management (IPM) seeks to use pesticides when other options are ineffective (Hassanali et al., 2008; Bale et al., 2008), the Integrated Nutrients Management (INM) recommends balancing both organic and inorganic fertilizers (Goulding et al., 2008; Ahmad et al., 2011, Ramasamy et al., 2013) for green production. Actually, owing to some serious concerns, sustaining the agricultural production growth and yields requires nowadays the application of Fertilizer Best Management Practice (Roberts, 2007) as a key technological innovation. Several classifications of technological innovations have been made to differentiate policies or modeling. For example, a categorization distinguishes between technologies that are embodied (such as machines, fertilizers, and seeds) and those that are disembodied (e.g., integrated pest management schemes, a set of new practices) (David and David, 2000). The technological progress function developed by Kaldor (1957) measures technological progress as the rate of growth of labor productivity. So, a technological change may cause the production-possibility frontier to shift outward, allowing economic growth. In this context, Lin et al. (2015), Yu and Ju (2011) and Wang and Zhou (2006), after measuring the contribution rate of scientific and technological (S&T) progress, suggested that the chinese industry sector, in particular the coal and construction industries, should rely on technological progress so as to improve the international competitiveness and realize the sustainable development goal. Except for S&T, a number of researches turned attention of government and practitioners towards agricultural technologies and practices concerns, and then, diverse statistical methods or mathematical models such as Cobb-Douglas production function, and Solow remaining value model, have been used to measure their contribution to agricultural production in the short and long terms (Suman et al., 2016; Venkatesan et al., 2004). Regarding chemical technologies, Kumar and Yaday (2001) found that the yield response of grains (rice and wheat intercropped) to a direct Nitrogen (N) fertilizer supply would decline over a long period, and in contrast, the application of Phosphorus (P) and Potassium (K) would increase the grains yields. Moreover, their findings revealed that a balanced dose of N-P-K is required to maintain durable soil fertility and raise grains yields.

Obviously, the increase on crop yields also related to many other factors. Some researchers basically drew attention upon the impact of human capital investments and fixed capital stock investments on agricultural gross domestic product, and some, investigated on the impact of irrigated land (Chao and Sun, 2013). In addition to the common factors of production (capital stock, labor force, land area), the range of agricultural technologies[2] considered in this article includes, mechanization, chemical technology, management practices and policies relating to cropping, as well as other agricultural infrastructures.

The main question raised in this research is how are agricultural technologies linked to the agricultural production growth? And what association of agricultural technologies should we deploy to sustaining the growth of agricultural gross domestic product? The research leans on the econometric analysis model based on Cobb-Douglas (C-D) production function so as to determine the influence of agricultural technologies on the increase in agricultural value-added in the country of Benin over the period 1990-2016. Moreover, the analysis is made on the system of technologies and practices that might foster a steady and sustainable growth of agricultural value-added (OECD, 2016; Sasmal, 2016). The corresponding suggestions according to the findings are put forward.

MODELING AND DATA DESCRIPTION

Theoretical modeling

The mathematical equation estimated in this study, based on Cobb-Douglas (C-D) production function, may be written as:

$$Y = A_0 \exp(\delta t) \prod_{i=1}^{p} X^{\alpha_i} \quad (1)$$

where Y is the potential output or income value, A_0 is the level of the output at base period, exp represents the exponential function, δ is the parameter of technological progress, t indicates the time variable expressing the influence of technological progress, p is the number of factors of production, X is a matrix of factors of production and α_i is the parameter of ith factor of production.

It may be demonstrated that the α_i are the output or income elasticity coefficients. Thus, seeking the partial derivative on X in Equation 1, we can get:

$$\frac{\partial Y}{\partial X_i} = \alpha_i \frac{Y}{X_i} \quad (2)$$

Hence,

$$\alpha_i = \frac{\partial Y}{\partial X_i} \times \frac{X_i}{Y} \quad (3)$$

X_i is the ith factor of production. The values of the α_i are obtained by applying the logarithm on both sides of Equation 1. Thus, the basic specification is given as follows:

[#] A country located in Western Africa, Benin is a tropical nation, highly dependent on agriculture, with substantial employment and income arising from subsistence farming.

[1] UN sustainable Development Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

[2] According to the World Intellectual Property Organization (WIPO), a technology is knowledge of a system to produce a product or provide a service. This knowledge may be a product or process invention, a form design, a practice, may also be a design management and other specialized skills.

$$ln(Y) = ln(A_0) + \delta t + \sum_{i=1}^{p} \alpha_i \, ln(X_i) \quad (4)$$

where $ln(Y)$ is the logarithm of the dependent variable. Moreover, the contribution rate in percentage of a factor of production to the growth of output or income may be calculated by the following equation.

$$E_{X_i} = \alpha_i \frac{g_{X_i}}{g_Y} \, x \, 100 \quad (5)$$

where E_{X_i} and g_{X_i}, are respectively, the contribution rate and the average annual growth rate of the ith factor of production; and g_Y is the average annual growth rate of the output or income.

Availability of data and materials

The dataset supporting the conclusions of this article is included within the article and its additional files. The modeling adopted is based on annual time series data of 27 observations (1990-2016) obtained from different sources, including the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Conference on Trade and Development (UNCTAD). Table 1 provides variable definitions and data sources.

Figure 1 describes the trend of annual growth rate of variables and it indicates that the evolvement of variables has not been steady over the period of study. The trends depict serious fluctuations of the growth rate of agricultural technologies and as a result, an unstable growth rate of agricultural value-added. In 2005 and 2010 (Figure 1a), the growth of agricultural value-added was negative, showing a certain drop in the value-added with a slight severity in 2010. These years in Benin represent the end of a political mandate, and the years before the beginning of new management policies. The highest growth rate is about 16.5% (2003) and attained by *IRRI*G whereas the lowest growth rate is about -6% (2006) and attained by *ALAND*.

Figure 1b presents information specific to the growth rate trend of chemical fertilizers uptake of which the peak is attained at 1942%. This evolvement raises some questions pertaining to the effect of chemical technologies on crop yields. Evidences have suggested that applying chemicals in a balanced ratio would be the best way to draw profit from these land-saving technologies (Roberts, 2007).

Figure 2 describes the linear relation between agricultural technologies and agricultural value-added. It indicates that the number of machines used, the number of hectares equipped for irrigation, and the number of hectares for arable land and permanent crops, are greatly related to the growth of agricultural value-added. Therefore, a linear model might explain correctly the relationship between the underlying variables. Thus, it is suggested to boost the growth of agricultural production in association with these underlying technologies. In contrast, the agricultural gross domestic product is likely to be inexplicable by the amount of chemical fertilizers in terms of linear relation in this study. However, owing to the role of this land-conserving technology, it is suggested to apply chemicals in a balanced ratio.

EMPIRICAL RESULTS

Unit-root test on variables

The Augmented Dickey-Fuller (ADF) tests (Table 2) showed that the null hypothesis that each variable (in logarithmic value)[3] does have a unit-root at level cannot be rejected. Then, variables were converted into first difference or second difference (*LIRRIG*).

Estimation of parameters α_i

Based on Equation 4, the growth of agricultural value-added is estimated (Table 3) by running the relevant econometric model containing an autoregressive component. Moreover, some *dummy* variables (*Dum1, Dum2*) are introduced in order to capture respectively the impact of sectorial development policy and strategy, and natural phenomena (e.g. flooding, precipitations). These variables influenced the growth of agricultural value-added since the null hypothesis that their coefficients are equal to zero cannot be accepted.

The regression model performs well, predicting 99% of the specified equation correctly. The causality between the growth of agricultural value-added and its determinant factors is established through F-statistic. All the diagnostic tests on residuals coming from the long-run model estimation (serial correlation, heteroscedasticity, normality) are desirable.

Prediction of the growth of agricultural value-added

Here, the study aims to analyze the gap between the forecasted value (*LAGRIVAF*) and the value of *LAGRIVA* estimated earlier named Actual value. The objective is to conclude on the goodness of the estimated regression model. Figure 3a pertaining to forecasted value indicates that the Root Mean Squared Error is set to only 1.146% and the curve of *LAGRIVAF* is passing through 95% confidence interval. The Theil Inequality Coefficient shows a perfect fit as well. As a result, we may conclude that forecasted and actual *LAGRIVA* are moving closely, and then, the predictive power of the estimated regression model is quite satisfactory. This can be observed in Figure 3b where both *LAGRIVA* and *LAGRIVAF* are plotted together.

DISCUSSION

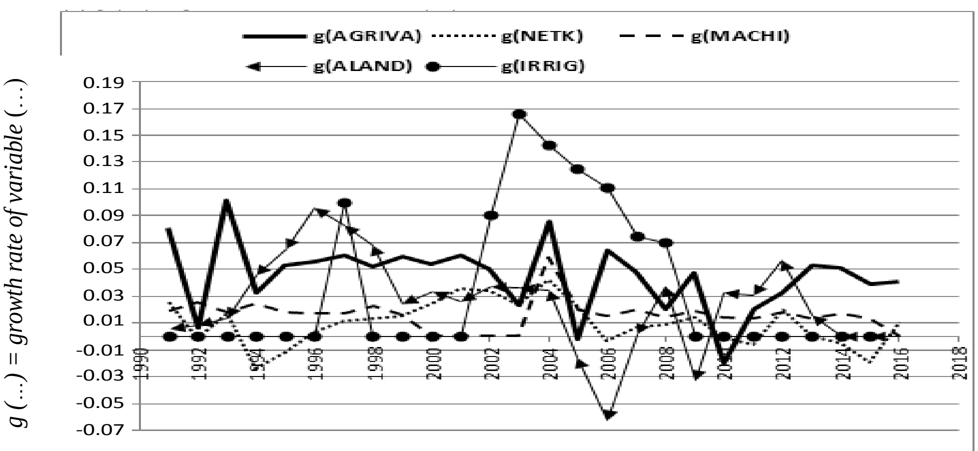
The results indicated that the growth of agricultural value-added (*AGRIVA*) is influenced by the technological progress, the net capital stocks value, the number of machines used, the number of hectares for arable land and permanent crops, the number of hectares equipped for irrigation, and the amount of chemical fertilizers consumed. The technological progress appeared at nearly 99% to be a major determinant of boosting the potential productivity of limited input factors, notably land factor (Shenggen, 1991). Thus, as time increases, technological changes occur, affecting positively the economic growth. In other words, when new farming devices and practices (e.g. multi-cropping, agroforestry, new varieties of seeds, new resources management) are

[3] LAGRIVA= Logarithm (AGRIVA)

Table 1. Variable definitions and data sources.

Variable	Definition	Sources
AGRIVA	Agricultural value-added (million local currency, value price 2005)	FAO (2017)
NETK	Net capital stocks value (million local currency, value price 2005)	FAO (2017)
MACHI	Number of machines (tractors, harvesters, threshers) used	FAO (2017)
CREDI	Amount of credits to agriculture (million local currency, value price 2005)	FAO (2017)
ENERG	Amount of energy used to power irrigation, in terajoule	FAO (2017)
LABOR	Number of workers in agriculture sector	UNCTAD (2017)
ALAND[4]	Number of hectares for arable land and permanent crops	FAO (2017)
FORES	Number of hectares for planted and naturally regenerated forest	FAO (2017)
IRRIG	Number of hectares equipped for irrigation	FAO (2017)
FERTIL	Number of tons for chemical fertilizers (nitrogen, phosphorus and potassium) consumed	FAO (2017)

(a)



(b)

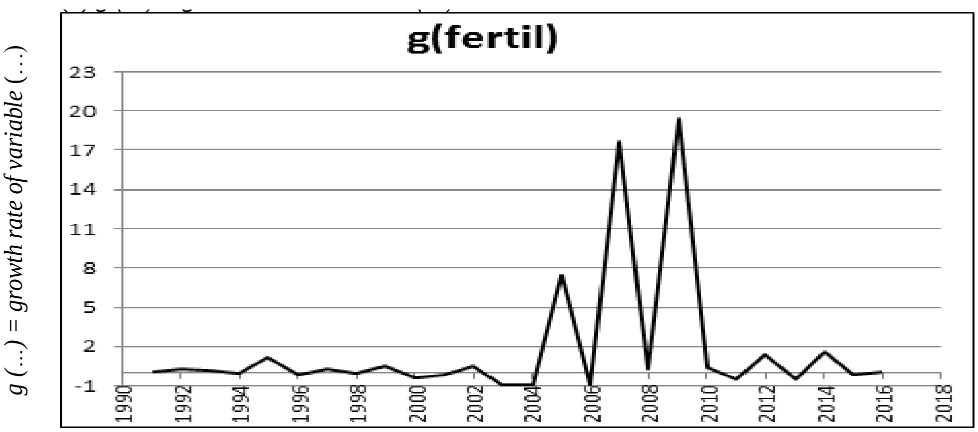


Figure 1. (a) Trends of annual growth rates of agricultural value-added, net capital stocks, machinery, arable land & permanent crops, and area equipped for irrigation (1990-2016). (b) Trend of annual growth rate of chemical fertilizers (1990-2016).

[4]According to the FAO, "Arable land" refers to land producing crops requiring annual replanting or fallow land or pasture used for such crops within any five-year period" (multiple-cropped areas are counted only once). A briefer definition appearing in the Eurostat glossary similarly refers to actual, rather than potential use: land worked (ploughed or tilled) regularly, generally under a system of crop rotation.

"Permanent cropland", meanwhile, refers to land producing crops which do not require annual replanting. It includes forested plantations used to harvest coffee, rubber, or fruit but not tree farms or proper forests used for wood or timber.

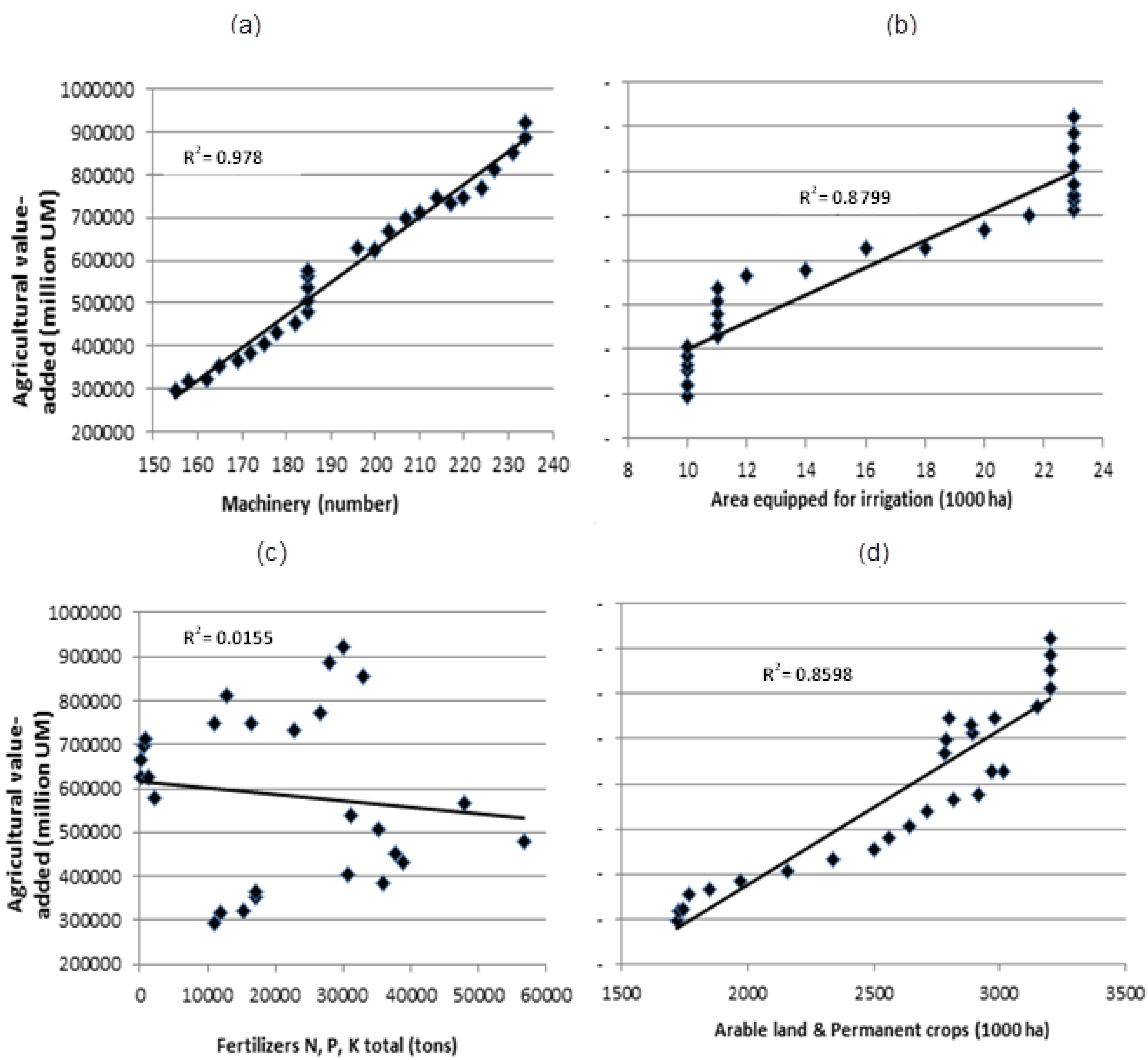


Figure 2. (a) Relationship between machinery and agricultural value-added (1990-2016) (b) Relationship between area equipped for irrigation and agricultural value-added (1990-2016) (c) Relationship between chemical fertilizers and agricultural value-added (1990-2016) (d) Relationship between arable land and permanent crops area and agricultural value-added (1990-2016).

adopted and introduced into the production process over the years, it might help to increase the total factor productivity. Currently the main driving factors of the economic growth in China are S&T progress and capital investment and the role of S&T progress is becoming increasingly important (Zhao, 2011; Qiguo and Jikun, 2011).

Indeed, the results showed that the amount of net capital stocks (*NETK*) does affect positively and significantly the agricultural gross domestic product. It is found that when farmers increase the capital stocks by 1%, the agricultural value-added would increase by about 0.59%. However, the presence of supporting infrastructure such as roads is fundamental (Dorward et al., 2004) and was a major factor in Asia's successful Green Revolution. The contribution of the factor *NETK* is established approximately to 13% in the present study. Wang and Yu (2011), state that China should make a large scale investment in agricultural capital as this factor appears to be greatly related to the growth of agricultural production value. This statement was put forward further to their findings regarding the Anhui province case study,

Table 2. ADF unit-root test on variables.

Variables	Unit-root test in	ADF test statistic	Test critical values	Integration order
LAGRIVA	First difference, including intercept	-6.926025	-3.724070***	I(1)
LNETK	First difference, without intercept nor trend	-2.730906	-2.660720***	I(1)
LMACHI	First difference, including intercept	-4.067870	-3.724070***	I(1)
LCREDI	First difference, without intercept nor trend	-11.40214	-2.664853***	I(1)
LENERG	First difference, without intercept nor trend	-4.898979	-2.660720**	I(1)
LLABOR	First difference, including intercept and trend	-3.924902	-3.673616**	I(1)
LALAND	First difference, without intercept nor trend	-2.077273	-1.955020**	I(1)
LFORES	First difference, including intercept	-3.674498	-2.986225**	I(1)
LIRRIG	Second difference, without intercept nor trend	-5.234235	-2.664853***	I(2)
LFERTIL	First difference, without intercept nor trend	-6.700149	-2.660720***	I(1)

***, ** Indicates significance at the 1 and 5% levels, respectively.

Table 3. Estimation of the growth of agricultural value-added [Sample: 1990-2016 (N = 27)].

Variable	Coefficient	S.E.
Constant	-103.5374**	34.48855
YEAR	0.041686***	0.011901
LNETK	0.586066**	0.203309
LMACHI	0.886031**	0.352736
LCREDI	0.003155	0.004138
LENERG	0.958764	1.200274
LLABOR	-0.029977	0.488572
LALAND	0.383954***	0.094556
LFORES	1.766482	1.259222
LIRRIG	-0.268012***	0.082152
LFERTIL	-0.004634*	0.002418
Dum1	0.079432***	0.015338
Dum2	-0.045332**	0.016504
AR(3)	-0.688183**	0.275643
Adjusted R^2	0.997	
F-statistic	800.48***	
Durbin-Watson stat (DW)	2.358	

***, **, * Indicates significance at the 1, 5 and 10% levels, respectively.

where the capital investment contribution rate is found to be about 92.59% over the period 1995-2006.

The number of machines is destined to capture the importance of agricultural mechanization (labor-saving technology). It is found that as the number of agricultural machines (*MACHI*) increases, so does the agricultural value-added. Thus, when agricultural production is mechanized, it might foster the drop of some production inputs (labor for example) and the saving of work time, and then, the increase in production value. The contribution of the factor *MACHI* is approximately established to 32% in the present study. This result is very close to that of Zhu and Cui (2011) in the case of China.

The number of hectares arranged for arable land and permanent crops (*ALAND*) was significant and did influence positively the growth of agricultural gross domestic product. This result is similar to that obtained by Luo and Huang (2013). Since this variable includes sustainable farming practices like multi-cropping, crop rotation and agroforestry, the probability that it is positively related to the sustainable agricultural growth is revealed as obvious and approximately 99% in this study. The practice of agroforestry on a farmland might be quite beneficial to a green agricultural revolution with some staple crops namely rice, corn and wheat. Permanent

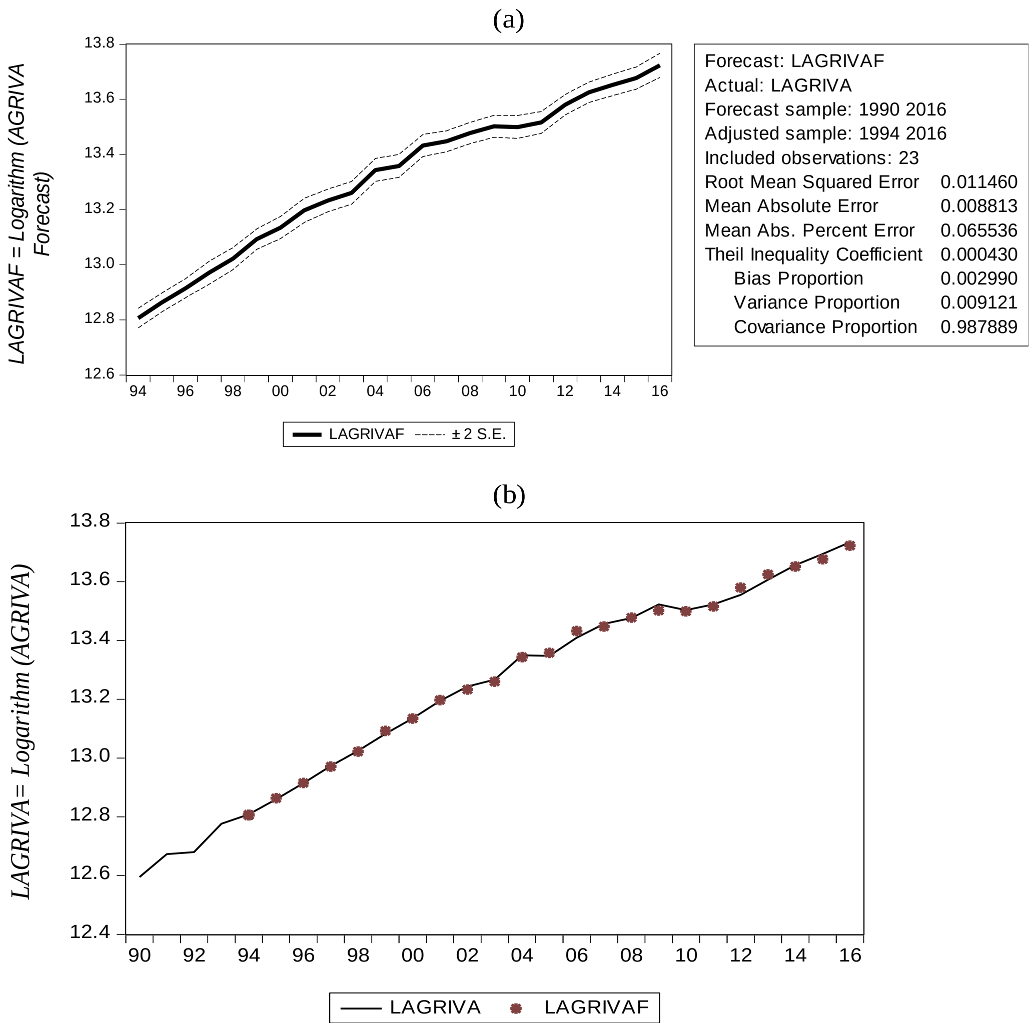


Figure 3. (a) Trend of forecasted growth of agricultural value-added (1990-2016). (b) Gap between actual and forecasted growth of agricultural value-added (1990-2016).

cropping may be encouraged and recommended as it seems to be an agricultural sustainability practice due to the fact that it may avoid ploughing more land, degrading soil, and so, may be playing an ecological role. In the country of Benin, the permanent cropping is carried out and derived products such as cashew nuts, mangoes, and palm oil are among the main commodities for exportation. The contribution of the factor *ALAND* is established approximately to 21% in the present study.

In addition, both the number of hectares equipped for irrigation (*IRRIG*) and the amount of chemical fertilizers (*FERTIL*) appeared to be negatively related to the growth of agricultural value-added. These results contradict those of Chao and Sun (2013), who found both of these technologies to have a certain and positive contribution to the agricultural economic growth. Many aspects must be considered in analyzing this outcome given that sometimes, the positive effects generated by applying land-conserving technologies may not globally compensate their negative externalities. Currently, the pursuit of the agricultural sustainable development goal in the country of Benin not only relies on chemical fertilizers, but also considers their mixture with organic manure. For all that and in relation with FAO (2015), it is recommended to use the underlying technologies in accordance with soil characteristics and in a balanced way. In this context, a further study may be interesting on how chemical and organic fertilizers should be managed in accordance with soil characteristics in order to sustain crop yields over time.

None of variables *LABOR*, *FORES, CREDI*, and *ENERG* were found to be significant determinants of agricultural value-added growth. In other words, the underlying variables are not likely to foster increasing directly the agricultural value-added. In the context of sustainable development, the labor force has to be strengthened with new knowledge and modern practices, otherwise, its impact on agricultural production growth in

Table 4. Impulse response of agricultural value-added (1-10 years).

Period	*LAGRIVA*	*LNETK*	*LMACHI*	*LALAND*	*LIRRIG*	*LFERTIL*
1	0.016548	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000938	0.001880	0.004575	0.003364	0.003025	-0.006375
3	0.009523	0.000622	0.008313	0.003506	-0.001925	-3.58E-06
4	0.005766	0.001267	0.011745	0.010891	-0.001772	-0.002663
5	0.000604	0.003451	0.007465	0.016807	-0.000977	0.003770
6	0.003461	0.005264	0.008238	0.018609	-0.005930	0.002293
7	0.000132	0.003888	0.005086	0.016867	-0.004091	0.001389
8	0.002821	0.002423	0.004726	0.012513	-0.004422	0.001753
9	0.004001	-5.71E-05	0.006643	0.009692	-0.003263	-0.000406
10	0.003092	-0.001353	0.006889	0.009398	-0.000784	0.001047

the long-term might be negligible in the presence of labor-saving technologies. Wang and Yu (2011) find that the insignificant impact of labor force in the province of Anhui in China is the fact of a huge number of rural labor force. Hence, the authors do propose measures to accelerate the transfer of the rural labor surplus, such as developing labor-intensive industries with deep-degree and fine processing of agricultural products, and so that, to promote a rapid development of the tertiary industry. Meanwhile, the contribution of the sub-sector of forest seems to be negligible. However, out of their economic role, forests recognize an environmental role like carbon dioxide sinks (positive externalities). In addition, it appeared that the credits received by farmers for the purpose of agricultural activity do not impact the growth of the agricultural value-added. An explanation may be the fact that the amount of credits received per farmer for investing is too insignificant to generate increasing returns to scale. Another explanation may be the fact that the provided loans required that farmers obtain reimbursement at a high interest rate or the credits may vanish due to an imperfect management. Lastly, it seems that the amount of energy used would only be affecting the functioning of irrigation equipment, and then, the contribution of the variable *ENERG* would be perceived through the impact of the variable *IRRIG*. For all that, it is suggested that a new method of management be implemented for labor force, forested area, agricultural credits, and energy used for irrigation, so as to render them more contributive to sustaining gross domestic production. A further study may investigate how rural demographic dividend can help a country solve the issue of food security.

IMPULSE RESPONSE OF AGRICULTURAL PRODUCTION GROWTH

Here, information on how agricultural value-added will be reacting within the short and long terms further to a positive innovation or shock to an agricultural technology is provided. The impulse response to Cholesky (d.f. Adjusted) One S.D. Innovations is thus presented in Table 4.

It is found that today's innovation to machinery and arable land and permanent crops area (Figure 4c, d) may be affecting positively and steadily the growth of agricultural value-added within 10 years (long term). Therefore, the goal of sustainable agriculture should rely on mechanized technologies and farming practices involving multi-cropping and agroforestry.

The growth of agricultural value-added may be responding positively to a net capital stocks impulsion (Figure 4b) in the short and medium terms (1-8 years), but it may be declining and turning into negative effect after 8 years (long term). Accordingly, it is advised that capital investments be reinforced or renewed at opportune moment so as to keep steady the positive trend of the agricultural economic growth over the years.

Figure 4e shows that the growth of agricultural value-added may be responding negatively within 10 years further to a shock to irrigation technologies. However, this negative response may be reversed after 10 years, indicating that once farmers do appropriate soil characteristics and other sub-factors relating to irrigation technologies management, these might later impact positively the production growth. Meanwhile, the positive response of *AGRIVA* to *FERTIL*'s impulsion (Figure 4f) is likely to dominate the negative effect in the long term (after 4 years). However, the impulse response is plainly negative in the short term. For sustainable agricultural goal, it is suggested that these chemical technologies be applied in a balanced ratio.

Furthermore, it is found that the output growth may be reacting successfully within 10 years when a shock is directly put to the overall production system (Figure 4a).

Conclusions

This research examined the influence of agricultural technologies on the growth of agricultural value-added

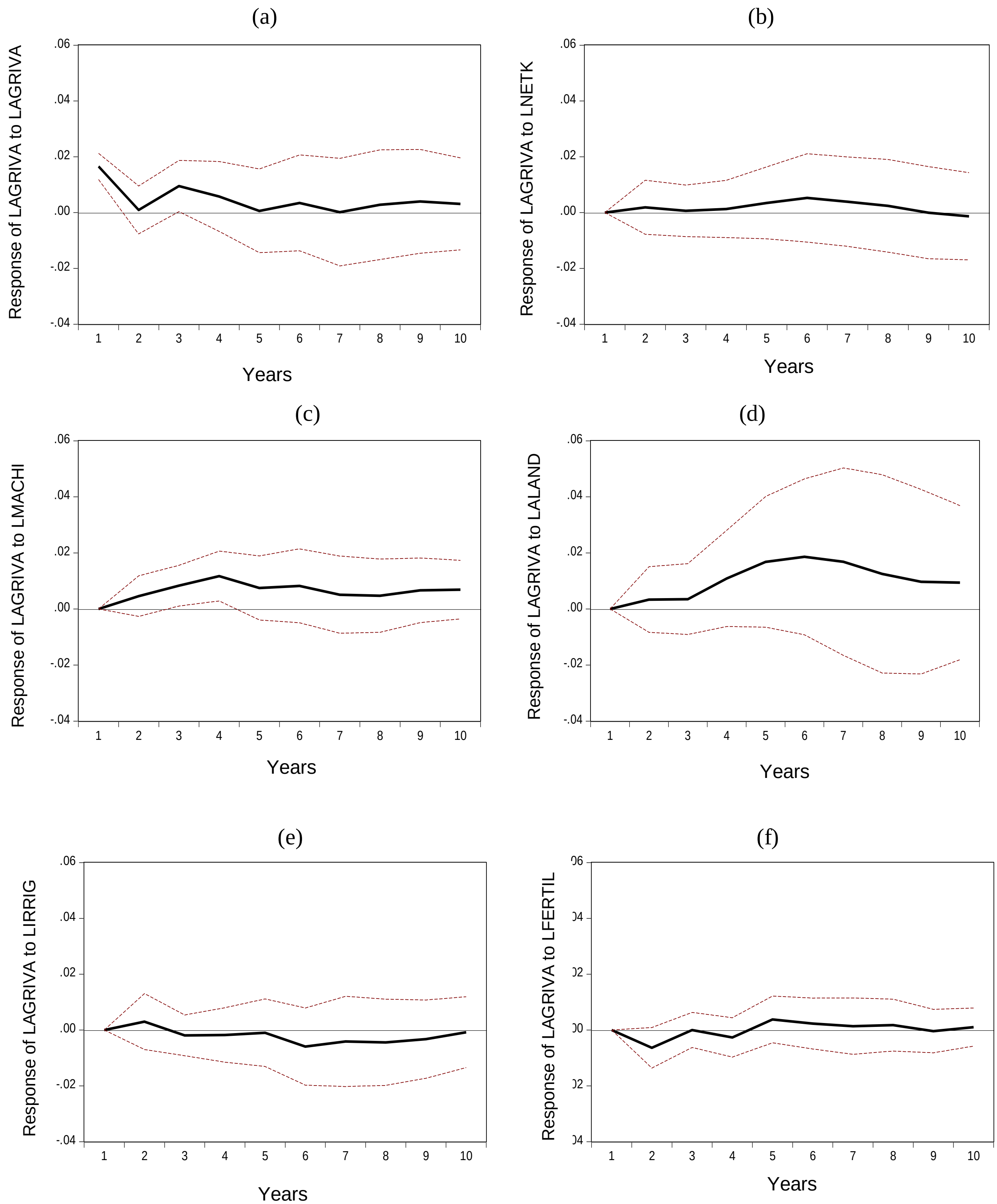


Figure 4. Projected growth rate of agricultural value-added in response to technological innovations (1-10 years).

based on time series data (1990-2016) and C-D production function. It determines that there is a positive link between the growth of agricultural value-added and the technological progress, the amount of net capital stocks, the number of agricultural machines used, and the number of hectares for arable land and permanent crops. Thus, there are significant and certain benefits to draw economically from the utilization of a system of technological innovations including mechanization, renewed capital stocks, and sustainable farming practices involving temporary cropping and permanent cropping. For the latter, farming practices like agroforestry and multi-cropping are largely revealed as satisfactory in number of country, and then, recommended for the sake of ecological concern. In contradiction to Chao and Sun (2013), it is found that both the number of hectares equipped for irrigation and the amount of chemical fertilizers are negatively related to the growth of agricultural value-added. However, technological shocks pertaining to irrigation and chemicals, as well as other agricultural technologies, might be beneficial for agricultural production growth in the long-term when they are perfectly managed. As a result, the adoption and diffusion of those technological innovations may impact positively farmers' welfare (Berihun et al., 2014; Khan et al., 2014; Mamudu et al., 2012; Solomon et al., 2012). Then, it is suggested that these technologies be used in accordance with soil characteristics and in a balanced way.

The results also indicate that the labor force, the forest area, the amount of credits to agriculture, and the amount of energy consumed to power irrigation are likely to be insignificant to boost directly the growth of agricultural value-added in the long-term. However, the different issues raised by the utilization of these factors must be addressed either by policy or by appropriating the knowledge relating to their good management so as to make them more profitable to agricultural production (MENG, 2012). In addition, sectorial development policies and strategies as well as natural phenomena are also significant determinants of agricultural production growth. Actually, the role of the central government is very crucial for a successful green agriculture (Dorward et al., 2004). In the light of all the forgoing, it is recommended that the goal of sustainable agriculture should be to consider a systematic approach associating technologies and practices that impulse positively the growth rate of agricultural value-added in the long term.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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